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MICROWAVE-INDUCED CATARACTS OF THE EYE LENS: STRATEGIES 1/1
FOR MODELLING AND (U) UNIVERSITY OF WESTERN ONTARIO
LONDON HEALTH SCIENCES CENTER. J R TREVITHICK MAY 86

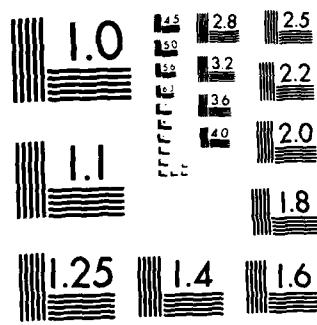
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MICROWAVE-INDUCED CATARACTS OF THE EYE LENS: STRATEGIES FOR
MODELLING AND PREVENTION IN VITRO AND IN VIVO

Annual and Final Report

DR. JOHN R. TREVITHICK

May 1986

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Summary: Block 19

Over the period of this contract, the initial aims of this project were to develop techniques for incubating intact rat lenses in vitro in order to study the development of cataracts when lenses are exposed to CW and pulsed microwave irradiation. We planned to (1) establish minimum cataractogenic SARs for irradiation in vitro and (2) investigate the mechanisms of cataractogenesis in such lenses.

Initial studies (see final report June 1981 for DAMD17-80G-9449) had indicated a linear correlation between depth of cataractous globular degeneration and temperature when the lens was exposed to a short period of temperature elevation and postincubated for a period of 48 hr. This unexpected linear relationship was found between 37°C and 50°C; in addition, at 47°C and 50°C some very large globules were formed. Surprisingly, at a higher temperature (60°C) the lenses had normal opacity and acuity, apparently because they had been fixed by the high temperature. D- α -tocopherol acetate when added to lenses before incubation at 41°C, prevented most of the globular degeneration observed at this temperature.

In initial attempts to expose the lenses to microwaves, a system was devised to rapidly circulate thermostatted coolant around the lens while it was being irradiated. This system permitted experimental separation of heating effects in the lens from effects due to electromagnetic radiation, since there was no measurable temperature elevation in the lens with respect to the surrounding medium even at highest microwave exposure levels tested. Irradiation was performed for two exposure times and at three SAR values.

The results of the irradiation indicated that the effect of the electromagnetic radiation itself could be considered to be equivalent to heating, since at the highest dose rate and 37°C, large globules were formed, which would otherwise have been reported only at 47°C, equivalent to a temperature elevation of 10°C. Pulsed irradiation at high SAR values appeared to result in holes in the surface of cells, consistent with the idea that thermoacoustic expansion is causing mechanical damage to cell membranes. An estimate of amount of damage experienced as a result of total dose level of microwaves was consistent with the idea that the amount of damage is roughly proportional to the total dose delivered to the lens, and that a reciprocal relationship exists between dose rate and time required to cause a defined amount of globular degeneration.

More work under the contract (DAMD17-83C-3051) was done to explore the possibility of reciprocity, which has important implications for personnel who are chronically exposed to low levels of microwaves as well as those suffering from the effects of acute exposure. Initial studies on pulsed microwave (Exp. Eye Res. 40, 1-13 (1985)) indicated reciprocity between exposure duration and dose rate. Further studies have indicated that more of the variation in depth of damage could be explained by a model in which the effects of duration and SAR were separated. Nevertheless, the reciprocal effects model may provide an adequate fit for practical purposes and has the advantage of greater simplicity. For both models the pulsed irradiation produced 4.7 times the depth of damage caused by CW irradiation. This difference is consistent with a

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Previous CW-Pulsed comparison by Marha used in setting up the Czechoslovakian safety standard which sets different standards for pulsed and CW irradiation (Marha, 1963).

The most recent work was done to compare the effects of varying pulse parameters likely to affect the pressure wave induced as a result of thermoelastic transduction. The operative pulse parameters to be studied were the pulse peak power and pulse duration. Work was done to explore these parameters under the contract extension until April 30, 1986. This work revealed significantly greater depth of damage at peak powers of 48 KW than with 24 KW peak power. The nature of the damage response to increases in average power and exposure time also was more pronounced. Deeper damage was observed at lower powers and exposure times for 48 KW pulse peak powers.

A more detailed analysis of the 48 KW data revealed significant increases in depth of damage associated with increased pulse duration, increased average power absorption and increased exposure time.

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FORWORD

A. List of Professional Personnel Employed on This Project

Principal Investigator - Dr. John R. Trevithick, Ph.D.
Research Associate - Dr. Margaret O. Creighton, Ph.D.
Research Associate - Dr. P. Jill Stewart-DeHaan, Ph.D.
Research Associate - Dr. Madhu Sanwal, Ph.D.
Research Associate - Dr. Peter Galsworthy, Ph.D.

B. Animal Care

In conducting the research described in this report, the investigator adhered to the "Guide for Laboratory Animal Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Science - National Research Council, U.S.A.

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A. INTRODUCTION

Microwave cataractogenesis is generally considered to be a consequence of the average power absorbed in the ocular lens. It is often stated that temperature elevation alone produces lens pathology (e.g., Cleary, 1980). In fact, Kramar et al (1975) concluded that a retrothalental temperature of 41°C is a threshold value for lenticular pathology (as determined by slit lamp examination) which may be associated with a SAR of ca 150 mW/g for ca 10^2 minutes of exposure. The results of Carpenter (1977) differed somewhat, since equivalent retrothalental thermal histories produced by treatments using, either 2450 MHz, or direct conductive heating by a ring applied to the sclera, produced different lens pathology. Also incidence of lens pathology was reduced from 5/6 to 1/16 respectively. Similarly rabbit retrothalental temperatures produced by restricting convective heat exchange via ear muffs and/or hot air directed to the ears, along with comparably reduced microwave dose, reduced the probability of lens opacity from 5/6 in the pure microwave case to 3/10 in the convection-restricted case. Carpenter concluded that retrothalental temperature elevation is necessary but not sufficient to produce cataracts.

Our results (Stewart-DeHaan et al, 1983) from in vitro exposures (where precise temperature regulation was possible) differed from Carpenter in that murine lens histopathology produced by heat was not produced by CW power at 1 GHz. The effects produced by CW power also persisted in the absence of net temperature elevation when lens temperature was controlled by flow of coolant over the lens.

The issue of the thermal origins of lens histopathology may be considered from another direction. If heat is the only pertinent parameter, "self" modulation should have no effect so long as the absorbed average power, temperature and duration are closely controlled. Pilot results reported in 1980 (Stewart-DeHaan et al, 1980) suggested that pulsed irradiation optimized for thermoelastic expansion (TEE) produced lens histopathology which differed in both qualitative and quantitative terms from that produced by CW irradiation of the same average power. To the extent that these findings are correct, the average heating produced by the field cannot be the sole operant parameter.

Comparisons of pulsed and CW microwave irradiation have been performed in the past. Weiter (1975) measured lens ascorbic acid (a biochemical precursor of lens opacification) in rats after 48 hours incubation prior to exposure to pulsed and CW fields of 150 mW/cm^2 power density at the site where the rat was later to be placed for exposure. The frequency of irradiation was 1500 MHz, the pulses were 1.18 long at a frequency of 500 Hz. Heat bath, CW power and pulse power produced equivalent changes indicating little difference in effects. Birenbaum et al (1976) studied pulse and CW fields of the same average power at 5.5 GHz in rabbits. The pulse width was 10 μsec ; the average power was 1 watt and the PRF was 500 Hz. The animals were exposed by a contact applicator consisting of a Stycast¹ dielectric lens and transition in close opposition to the conjunctive and cornea. A different assay, by slit lamp examination, failed to show any difference in threshold between CW and pulsed exposures (Carpenter, 1962). In these experiments Carpenter used 2450 MHz and

¹ Trademark, Emerson & Cummings, Inc. Canton, MA.

9375 MHz: the pulsed exposures were at a 5% duty factor and an average power density of 140 mW/CW². Although the results were ambiguous, it has become increasingly frequent to cite this study as failing to show effects. One report of lens pathology from pulsed exposures (Richardson, 1951) has neither a CW comparison nor a suitable description of exposure conditions.

It has been shown that pulsed fields can elicit elastic waves in biological target organs: the potential of ocular hazards (Neelakartaswamy and Ramakrishnan, 1978, 1979) secondary to thermoelectric expansion has been cited as a new hazard mechanism, but no experimental evidence was presented.

The comparison of the extent of effects from pulsed and CW irradiation and the role of TEE as an additional mechanism for damage by pulsed microwave irradiation is important not only because of the generally held view that heating and associated temperature elevations are the only causative mechanisms of lens pathology. It also suggests the possibility of serious hazards arising from high peak power microwave emitters with low duty factors. In such situations the question arises if the hazard potential of the field is dependent only on average power of the field, or whether TEE-dependent effects may result in added hazards not presently appreciated. Since prior work has not fully addressed these issues in light of TEE theory we decided to perform the following experiments which determine effects of CW irradiation and to compare these results with previously reported results and additional new results for pulsed microwave irradiation at similar average powers.

In our previous (Stewart-DeHaan, et al, 1984) report, it was shown that the reciprocal model $DEP = (POW \times TIME)^{.72}$ provided a good fit to the observed depth of damage to the ocular lens caused by pulsed wave irradiation. Our 1985 annual report presented results of a similar analysis comparing pulsed to continuous wave irradiation. In this report this data is repeated and models developed to incorporate results for both continuous and pulsed waves, are further expanded to explore (i) effects of increasing peak pulse power and (ii) effects of changing pulse duration.

E. MATERIALS AND METHODS

After dissection, lenses of Sprague Dawley (Walter Reed strain) rats, 180-200 g average weight, with intact capsules, were either temporarily placed in phosphate-buffered saline in culture tubes or immediately transferred to the exposure cell described in a previous publication (Stewart-DeHaan, Creighton, Larsen, Jacobi, Ross, Sanwal, Guo, Guo and Trevithick, 1983) (Fig. 1) in which they were bathed by circulating phosphate-buffered saline (PBS) during exposure to microwave irradiation in WR95 wave guide at 918 MHz (Stewart-DeHaan et al, 1980, 1983). In lenses fixed immediately after irradiation, damage is observed in roughly a wedge shaped ring at the equator, with the apex of the wedge penetrating towards the nucleus. When damage occurred posteriorly and anteriorly it was found in a thin layer beginning at the capsule and proceeding inward towards the lens nucleus.

Lenses were irradiated, fixed immediately, then processed and examined either by scanning electron microscopy as we previously described (Stewart-DeHaan et al, 1983) or by light microscopy of 1 μ thick plastic sections of lenses, embedded in glycol methacrylate.

The average transmitted power was absorbed completely by the sample in the tuned waveguide system. Specific absorption rates for this system were measured previously without buffer circulating through the hoses connected to permit circulation of saline. Repeating this measurement, with saline not circulating but filling the hoses, using an microwavetransparent Luxtron probe to measure the temperature resulted in a decrease in SAR to approximately half that measured previously. With no saline in the hoses, the SAR values we previously reported were confirmed. The actual SAR values (for saline) at the location of the lens in the irradiation cell, with corresponding average transmitted powers, were: power (SAR) 2 W (23 mW/g), 6 W (69 mW/g), 20 W (231 mW/g), 65 W (750 mW/g). For comparison, those we previously reported (and confirmed) were 2 W (40 mW/g), 6 W (120 mW/g), 20 W (400 mW/g) and 65 W (1.3 W/g). The pertinent formula for calculation of the SAR, modified by Lin et al, 1978, from the original formula of Johnson and Guy (1972) (SAR (w/cc) = $4.18 \frac{c}{T/t}$), to permit expression in W/g instead of W/cc, is SAR $\frac{W/kg}{T/t}$ = $4.18 \frac{c}{T/t}$, where c is the specific heat of the sample in cal deg $^{-1}$ g $^{-1}$, f is the density in g/cc, 4.18 is a constant for unit conversion (1 calorie = 4.18 joules), and T is the temperature elevation in $^{\circ}$ C during the exposure duration t in seconds. For the calculation we assumed the specific heat of water to be 0.998 cal deg $^{-1}$ g $^{-1}$ and the density 0.998 g/cc for saline. Experiments are in progress to determine the actual values for heating.

Five separate conditions, at different times and average powers to permit the same total energy to be delivered during 6, 20 or 60 minutes of irradiation, at different SAR values, 11.5, 23, 69, 231 mW/g and 750 W/g, were examined for both CW and pulsed microwave: 0.23 watt-min/g, 0.46 watt-min/g, 1.31 watt-min/g, 6.9 watt-min/g, and a maximum of 15 watt-min/g.

Microwave irradiation was delivered to the lens in the pulsed mode with 10 μ sec, 10 μ sec and 20 μ sec pulse width and 24 KW and 48 KW of peak transmitted power. Repetition rates were varied to obtain the various average powers.

For each lens in which damage could be observed, granular degeneration occurred in a depressed ring in the zonular region and around the lens equator, with the apex of the depression towards the lens nucleus (see Results). The maximum depth of degeneration was measured at the deepest penetration of the damage. Measurement was made in the region 40-60 μ m immediately posterior to the centre of the zonular attachment to the exterior of the capsule. The measurement was made from the inside of the lens capsule to the assessed maximum depth of visible damage. The two determinations, one on each side of the lens) were averaged (since they were usually quite similar and that average represented an observation in the analysis. If only one determination was possible, this determination alone was used. This occurred only in three lenses, all being exposed to pulsed waves for radiation. These values were used to determine the average of maximum depths of damage for the particular condition chosen. All determinations were performed blind using a numerical code and the code broken after the analyses were complete.

C. STATISTICAL ANALYSES

C. 1 Initial Pulsed-CW Comparisons

An analysis of the effects of pulsed vs continuous wave irradiation on the ocular lens was performed. The purpose of the analyses was to compare the depth of granular degeneration (DEP) produced by continuous and pulsed wave irradiation at various dose rates (POW) and lengths of exposure (TIME).

A one-way analysis of variance (ANOVA) was performed on the continuous wave data alone and the means for the 11 combinations of POW X TIME compared using the modified Tukey method in multiple comparisons (1953). Such an analysis has been reported previously on pulsed microwave irradiation (Stewart-DeHaan, 1985).

In order to test reciprocity between duration of exposure and dose rate, overall, two alternative models fit to continuous wave and pulsed data were used:

$$(1) \text{ DEP} = b_0 (\text{POW} \times \text{TIME})^{b_1} e_1$$

$$(2) \text{ DEP} = b_0 (\text{POW})^{b_1} (\text{TIME})^{b_2} e_2$$

The first model states that POW and TIME act in a reciprocal fashion to determine the depth of damage and is referred to as the reciprocal effects model. Model (2) allows for the possibility of separate effects of POW and TIME through coefficients b_1 and b_2 . In both models e represents a random multiplicative disturbance. Overall comparison of pulsed and CW effects was conveniently performed, using these models, for both sets of data.

The adequacy of model (1) was tested against the alternative expressed by model (2). Since both models were log-linear this was done by fitting the transformed models

$$1 \quad \ln(\text{DEP}) = \ln b_0 + b_1 \ln(\text{POW} \times \text{TIME}) = \ln e_1$$

$$2 \quad \ln(\text{DEP}) = \ln b_0 + b_1 \ln \text{POW} + b_2 \ln \text{TIME} = \ln e_2$$

by multiple regression. It was assumed that $\ln e_1$ and $\ln e_2$ were normally distributed with mean zero and variances σ_1^2 and σ_2^2 respectively.

Inspection of the results in 1 suggested that the depth of damage produced by the two radiation types differed by a multiplicative constant, thus the reciprocal model

$$(3) \text{ DEP} = b_0 b_1^x (\text{POW} \times \text{TIME})^{b_2} e^{b_3}$$

was proposed, where $x = 0$ for continuous waves and $x = 1$ for pulsed waves.

$$(4) \text{ DEP} = b_0 b_1 (\text{POW})^{b_2} (\text{TIME})^{b_3} e.$$

The linear forms of these models were:

$$(3') \ln(\text{DEP}) = \ln b_0 + x \ln b_1 + b_2 \ln(\text{POW} \times \text{TIME}) + \ln e$$

$$(4') \ln(\text{DEP}) = \ln b_0 + x \ln b_1 + b_2 \ln(\text{POW}) + b_3 \ln(\text{TIME}) + \ln e.$$

These models were fit to the combined data using multiple linear regression.

A second one-way ANOVA was performed including data for pulsed and continuous wave irradiation at each of 10 POW X TIME combinations. The method of contrasts was then used to compare the two means at each combination of POW X TIME.

C. 2 Most Recent Pulsed-CW comparison

C.2.1 Comparison of 24 and 48 KW Series at 10 μ s

In (1) the comparison of 24 and 48 KW peak powers was confounded with different pulse widths (10 and 20 μ s). In this analysis of the new data from 24 and 48 KW series at 10 μ s was used so that the effects of changing peak power alone could be examined. There was, however, another complication in this comparison being that the 24 and 48 KW series were done with a different configuration of the apparatus with the result of different actual absorption of the pulse emitted (POW). To account for this in the analysis the actual power absorbed (NPOW = .4375 x POW, for 48 KW data) was used as a covariate in analysis of covariance (ANCOVA). Thus the comparison of 24 and 48 KW means is a comparison of means adjusted for the discrepancy in absorbed irradiation. ANCOVA makes this adjustment based on the observed correlation between NPOW and depth of damage.

This analysis was performed with the subprogram ANCOVA from SPSS '2'.

C.2.2 Reciprocal and Separate Effects of Exposure Time and Average Power at 10 μ s and 100 μ s

Again this analysis was similar to that contained in (1) using data for 10 μ s to yield a more direct comparison with the results from 24 KW at 10 μ s which were:

$$(1) \text{ DEP} = (\text{POW} \times \text{TIME})^{.72}, R^2 = .78$$

$$(2) \text{ DEP} = (\text{POW})^{.67} (\text{TIME})^{.83}, R^2 = .79$$

The values used for average power where the amounts actually absorbed (NPOW) to make the coefficients comparable.

C. 4 Revised Comparison of Previous and New 24 KW Results

This analysis consisted of fitting the 12 observations from the new series to the separate and reciprocal effects models with POW replaced by NPOW. The coefficients of the resulting models were tested against those given in the section above.

C. 5 Three Factor ANOVA

Observations taken at 2, 10 and 20 μ s pulse widths were combined in an analysis of variance (ANOVA) for the $4 \times 3 \times 3$ (POW X TIME X PW) factorial design. This analysis was also performed using the ANOVA subprogram in SPSS (Version 9.0) (2). In this analysis the main effects of each factor were assessed with the other two factors held constant. Similarly the two and three-way interactions were assessed with all main effects and other interactions of the same or lower order held constant. This means, for example, that the test for the main effect of PW was based on the variation attributable to that factor after the variation attributable to POW and TIME had been accounted for.

C. 6 Three Factor Regression

Two regression models were fit to the complete set of observations taken at 24 KW. The first allowed for reciprocal effects of POW and TIME with no effect of PW. The second provided for separate estimates of the log-linear effects of these factors. The actual amount of irradiation absorbed (NPOW) was used to make the results comparable to previous models.

D. RESULTS

D. 1 Lens Damage Observed with Pulsed and CW Microwave

For lenses fixed immediately after exposure the damage observed was of several types: (1) holes within the fiber cells, especially in the region of capsular attachment in the equatorial region, (2) capsular effects, such as pitting or surface granulation, (3) globular degeneration, sometimes covering large subcapsular regions but mainly within the capsular attachment and equatorial region, (4) foam, located immediately subcapsularly within the same region and (5) granulation of fiber cells, which can extend deep within the lens (Stewart-DeHaan, 1985). Incubation of the lens for a further 48 hr. as previously reported (Stewart-DeHaan et al. 1983, 1985) results in more obvious damage as effects on cell membrane integrity are expressed in more advanced damage: globular degeneration and foam.

Although some damage was seen in lenses fixed immediately after exposure to pulsed microwaves, the threshold at which damage was observed in 50% of the lenses (TD_{50}) varied depending on the type of damage (Table 1). For lenses exposed to CW waves, not all types of damage were seen; usually the TD_{50} occurred at higher powers than the TD_{50} observed for pulsed microwaves (Table 1).

Except for the similar effects observed for both pulsed and CW irradiation after 60 minutes exposure to 1/2 W (10 mW/g) average power, the lowest power at which damage was observed occurred at lower average powers for pulsed irradiation than for CW. Conversely, when compared only by ANOVA, for the same average SAR (or power) x time combinations, the damage observed following pulsed irradiation was always greater than for CW, and at higher average powers the damage was much more extensive. For instance, at 65 W, the damage from pulsed irradiation was extensive: irregular, jagged areas of granular degeneration intruded deep into the cortex, while the CW irradiation only resulted in small areas of granular degeneration at the lens equator. A diagrammatic view of changes observed in the area of the lens equator after pulsed and CW irradiation different durations and SAR values is seen in Fig. 2-4. In figures 2 and 3, CW (Figure 2) and pulsed (Fig. 3) irradiation effects are represented diagrammatically after exposure for the same lengths of time 6 min. 20 min and 60 min. In Figure 4, at the threshold value for the first observable damage at the lens equator (for either pulsed or CW), this damage may be compared to the amount of damage shown by CW or pulsed, respectively. For instance in Fig. 4c the lowest pulsed power level at which damage is observed is compared to Fig. 4d, which illustrates the absence of any comparable damage after the same CW power level and time. The more extensive damage caused by pulsed irradiation (Fig. 4e) at the CW threshold exposure (Fig. 4f) (20 W, SAR 230 mW/g) is compared in Fig. 4e and 4f. Finally the relative depth of damage is compared for pulsed (Fig. 4g) and CW (Fig. 4h), resulting in a ratio of pulsed/CW damage of approximately 3.0 at the maximum SAR (65 W SAR 750 mW/g).

For irradiation at 20 minutes, the lowest power (Fig. 5c) at which the pulsed irradiation caused discernable damage was 1/2 W (SAR 518 mW/g). At this average power, no damage was apparent in the CW-irradiated sample at the same power. At the lowest CW power at which damage could be observed (2 W, SAR 23 mW/g) (Fig. 5c) the pulsed irradiation caused significantly more damage (30 μ m deep). The maximum damage, at 65W (SAR 750 mW/g) (Fig. 5g) is observed to be approximately four times as deep for pulsed, as compared to CW, irradiation (Fig. 5h).

Following 60 minutes irradiation (Fig. 6), the minimum damage occurred for both pulsed (Fig. 6c) and CW (Fig. 6d) irradiation at 1/2 W average power (SAR 518 mW/g), although slightly more damage occurred with pulsed than with CW irradiation. At an intermediate power level (Fig. 6e, f, SAR 60 mW/g), the pulsed irradiation caused damage to approximately 3.1 times as great a depth as the CW irradiation at the same average power (50 μ m vs 15 μ m). At the maximum average power (65 W, 750 mW/g) (Fig. 6g, h) the ratio of depth of damage for pulsed/CW irradiated samples was approximately 1.5.

Statistical evaluation of the data was performed to evaluate the data, shown in Table 2. As in the previous results for pulsed irradiation (Stewart-DeHaan et al, 1984), the continuous wave irradiation produced increasing depth

of damage with increasing dose rate and increasing time of exposure (Fig. 5). Pulsed wave irradiation produced consistently greater depth of damage than did continuous wave irradiation except at the 2 watt 6 minute combination. The pulsed CW differences were subjected to detailed comparison at 10 different combinations of POW X TIME.

E. 2 Models for Continuous Wave Irradiation

The estimated models (1)' and (2)' are shown in Table 3. The means for the data used are given in Table 2. The separate effects model, $DEP = 0.4(POW)^{.82}(TIME)^{1.22}$, accounted for 76% of the observed variation in DEP while the reciprocal mode, $DEP = .10(POW \times TIME)^{.88}$, accounted for 67% of this variation. The F test shown in Table 4 showed that for the continuous wave data the separate effects model explained significantly more of the observed variation in DEP.

The 95% confidence intervals for the parameters estimated in models (1) and (2) are given in Table 5.

E. 3 Models for the Combined Data for 24 KW, 10 μ sec pulses compared to CW

The fitted equations for models (3)' and (4)' are given in Table 6. The separate effects model $DEP = .09(4.66)x(POW)^{.67}(TIME)^{.74}$, explained slightly more of the variation in depth of damage than the reciprocal effects model, $DEP = .15(4.71)x(POW \times TIME)^{.78}$. Table 7 shows that this small difference was significant or the separate effects model explained significantly more of the observed variation in depth. The means for the additional pulsed wave data used in this analysis are given in Table 8.

The 95% confidence intervals for the parameters estimated in models (3) and (4) are given in Table 9.

E. DISCUSSION

E. 1 CW Compared to Pulsed Irradiation (24 KW, 10 μ sec pulses)

The thermogenesis of ocular lens histopathology remains an issue of importance in microwave biomedical research. Its importance derives from two factors: the need for improved biophysical understanding of the mechanism of histopathologic effects secondary to microwave exposure, and the need to insure safety under conditions of exposure to high peak power microwave emissions where the average power absorbed may not fully represent the hazard.

The results described here clearly indicate that for microwave irradiation at 918 mHz modulation of the signal to produce 10 μ sec pulses results in more damage at the same average power for every combination tested except one (2 W SAR of 23 mW/g for 6 min). Although the separate effects models explained significantly more of the variation in depth of damage, the reciprocal models may provide an adequate fit for practical purposes with the advantage of greater simplicity. This is particularly true in the case of the combined data where the actual difference in F' may be of little practical importance but was significant because the large number of observations produced a very powerful test.

The graphs of both models, showing their fit to the 24 KW peak pulse power data, are given in Figure 7 and 8. For both models 3 and 4 the pulsed irradiation produces $4.7 \times$ the depth of damage caused by the CW mode. Of the several mechanisms by which such additional modulation-dependent damage could occur, (viz. thermoelastic expansion (TEE), electrostriction effects (ESE) etc. the most likely mechanism is TEE, resulting in pressure waves induced in the aqueous medium and lens tissue by thermoacoustic expansion following each pulse of microwave energy. The acoustic measurements previously performed and reported elsewhere (Guo, Guo and Larsen, 1984) are consistent with such a mechanism: pressure waves are induced by each pulse. These are capable of causing the additional types of physical damage previously noted for pulsed microwaves - holes in cell membranes, large globules at higher power etc. This work thus provides evidence for significantly increased damage as a result of signal modulation at the same average power and wavelength. The work of Martha (1963) on biological damage by CW and pulsed microwaves used to irradiate whole rats supports the idea that high energy pulsed irradiation causes significantly more biological damage even at the same average power of irradiation. Our findings confirm this in indicating approximately 4-5 times greater damage for pulsed wave irradiation as compared to CW irradiation. Although the irradiation pulses were only 2 μ sec duration they would have been able to cause a significant thermoacoustic effect. For this reason we continued to compare pulses of different duration and peak powers.

F. RESULTS

F. 1 Comparison of 24 and 48 KW Series at 10 μ sec

Tables 10 and 11 show the data used in this analysis. The results of ANCOVA are given in Table 12. The absorbed irradiation (NPOW) had a significant positive correlation with depth of damage. When peak power means were adjusted for the discrepancy in absorbed power the result was that 48 KW produced significantly deeper damage ($p = .02$). Greater time of exposure also produced significantly more damage ($p = .001$). The significant PP X TIME interaction indicated that the effect of peak power varied from one exposure time to another. Since the adjusted means were not broken down by PP X TIME it was not possible to comment on the nature of this variation.

F. 2 Reciprocal and Separate Effects of Exposure at 48 KW and 10 μ sec

The reciprocal and separate effects models obtained from the 48 KW results at 10 μ sec were:

$$\text{DEP} = 8.58 (\text{POW} \times \text{TIME})^{1/2}, R^2 = .55$$

$$\text{DEP} = 9.76 (\text{POW}^{1/2} \times \text{TIME}^{1/2}), R^2 = .56$$

Neither model showed as good an overall fit to the 48 KW data as it did to the 24 KW data in terms of the coefficient of determination (R). As for the 24 KW data there was little to choose between the reciprocal and separate effects models on these grounds (.55 vs .56). Both models contained positive multiplicative constants with smaller effects of POW and TIME. This would indicate greater depth of damage at lower levels of POW and TIME that happened

out more quickly than for the 24 KW results. This is illustrated in the damage by power profiles of Figure 9. However, these results must be interpreted with some caution due to the lack of observations for high levels of absorbed irradiation in the 48 KW series.

The coefficients in these models were all statistically significant ($p < .001$), showing a significant log-linear relationship of depth with PCW or TIME or (POW X TIME).

F. 3 Revised Comparison of Previous and New 24 KW Results

Table 13 gives the data from the series run on the new apparatus at 24 KW. When this data was fit to the reciprocal and separate effects models with average power adjusted to reflect the amount of irradiation actually absorbed the results were:

$$1. \quad \text{DEF} = 8.17 (\text{POW} \times \text{TIME})^{.41}, R^2 = .82$$

$$2. \quad \text{DEP} = 6.89 (\text{POW}^{.37} (\text{TIME})^{.40}, R^2 = .84$$

These regression functions showed some evidence of change from the original series ($p = .06$ and $p = .11$, respectively).

F. 4 Analysis of the Complete 48 KW Data

F.4.1 Three Factor ANOVA

Tables 14, 15 and 16 give the mean depth of damage at 48 KW for pulse widths of 2, 10, and 20 μ sec. broken down by average power and time. The results of the three factor ANOVA are summarized in Table 17 and illustrated in Figures 10-12.

Depth of damage increased significantly with increases in each of the three factors. Figure 10 shows that the damage profiles were not parallel when examined by POW and PW. This accounts for the significant PW X POW interaction ($p = .001$). Figure 11 shows the situation for PW X TIME with the lack of increase from 10 to 20 μ sec with a 6 minute exposure time being largely responsible for the significant interaction ($p = .001$). The relatively parallel profiles of damage by power and time in Figure 11 explain the lack of a POW X TIME interaction ($p = .70$). The significant three way interaction indicates that each two-way profile would differ if plotted for each level of the third factor.

F.4.2 Three Factor Regressions

The following results were obtained from regression analysis as described in Section 2.4.2.

$$1) \text{ DEP} = 13.6 (\text{POW} \times \text{TIME})^{.35} (\text{PW})^{-.09}; R^2 = .47$$

$$2) \text{ DEP} = 12.2 (\text{POW})^{.35} (\text{TIME})^{.37} (\text{PW})^{-.09}; R^2 = .47$$

The coefficients (exponents) of PCW, TIME, or their product were significant in both models ($p < .001$) as were the constant multipliers ($p < .001$). The coefficient of PW was not significantly different from zero ($p = .01$) in either model and this term could be dropped.

The proportion of variation explained (R^2) was not high for either model. The value of R^2 for the ANOVA model discussed in Section F.4.1 was considerably higher (.70). This was due to the fact that the regression model did not provide for interactions between all the factors. Such interactions explained a significant amount of variation in ANOVA. This also accounts for the fact that the effect of PW was significant in ANOVA but not in these particular regression models.

F. 5 Prior Work and Its Interpretation

Prior work has been interpreted to reach the conclusion that exposure to pulsed CW irradiation of the same average power results in a similar degree of damage for biosystems. It has been felt that this danger is largely, if not solely, the result of average temperature elevation (Cleary, 1980). The historical base on which this conclusion is reached can be interpreted differently, especially in light of thermoelastic expansion theory. Even so, Carpenter (1966) remains skeptical that pulsed and CW fields are equivalent, but his data are not sufficiently clear to reach a firm conclusion. In view of the TEE mechanism, Carpenter's pulse exposures were done at an extraordinarily low duty factor (50%) at an average power density of 140 mW/cm^2 . Thus, the pulse width was much too long to produce TEE efficiently, according to equations developed to calculate the thermoacoustic transduction (Lin, 1978). The absence of SAR data and the coupling iris used for the X-band pulse exposures make interpretation of this study difficult.

The work of Birenbaum et al (1969) is more often cited as evidence for the equivalence of pulse and CW effects. This experiment was done with a series of 100 rabbits exposed to pulsed microwaves and 61 exposed to CW. Birenbaum et al used a variation of a contact applicator method devised by Carpenter (1968). The Birenbaum applicator consisted of a section of dominant mode "C" band rectangular guide (WR187) followed by a transition to double ridged guide with Styrofoam ($\epsilon_r = 12$, $\tan \delta = 0.001$) dielectric loading between the ridges. This was followed by a transition to circular guide completely filled with the Styrofoam dielectric. This final section was .595" (1.51 cm) in diameter, 0.458" (1.23 cm) long and machined for a concave (1.135" (2.88 cm) hemisphere into which the animal's eye was placed. The eye lid was sutured open and a pseudo tear film layer was applied to the conjunctive-cornea. The exposures were performed at two average powers: 1 watt and 1.1 watt. No differences were detected between pulse and CW exposures at the same average power for 5 usec pulses at a 10^{-3} duty factor. This suggests that the peak energy was 5 mJ over an aperture of 1.51 cm² to result in a peak energy

density of about 4 mJ/cm^2 . This should have been a sufficient energy density and reasonably efficient pulse width for the frequency of operation to achieve TEE. Yet no differential effect was observed.

The reason that no differential effect was observed may have been a consequence of the applicator and the biological end points. Firstly, the applicator prevented normal evaporative cooling of the cornea. Secondly, the applicator was likely to be at an elevated temperature. Based on a $\tan \delta$ of 0.001 and $\epsilon' = 12$, the ϵ'' was 1.2×10^{-2} . The SAR of the Styrofoam dielectric may be estimated from $\text{SAR} = (0.556 \times 10^{-3}) \epsilon'' \cdot 1 \text{ E}^2 \text{ (watts/cm}^3\text{)}$ which yields approximately $1.8 \times 10^{-3} \text{ watt/cm}^3$. The volume of the end piece was ca $1.4/\text{cm}^3$ and its density is 2.24 g/cm^3 . Given the relationship between SAR and temperature elevation per unit time $\text{SAR} = 4.186 \text{ }^{\circ}\text{C}/\text{t}$ (Johnson and Guy, 1972; Stewart-DeHaan et al., 1983) where ρ is the density in g/cc and c is the specific heat and based on a specific heat in the order of unity, the temperature rise would be ca $1/8^{\circ}\text{C sec}$. The exposure duration was 3 min which would give an end temperature of the front applicator surface (ignoring heat transfer to the guide) of ca 20°C . This added to base line temperature of 23°C and allowing complete cooling between runs would place the applicator at ca 43°C directly on the conjunctiva/cornea. This is a sufficient thermal insult to dominate any other aspect of the exposure. In fact, there is ample evidence cited in Birenbaum's results of acute anterior chamber effects in both the pulse and CW groups. This includes "acute, inflammatory reactions of the cornea, conjunctiva, iris and/or ciliary body were observed in many and probably produced in every exposed rabbit eye". These reactions were "frequently severe" and has "usually subsided by the fourth day".

Additional evidence of a primary anterior chamber effect due to corneal heating and thermal diffusion to the lens is the observation that lens opacity was usually long in latency (2 to 3 weeks post exposure) and "was present in the anterior portion of the lens". This is unusual with respect to the latency. Carpenter (1977) observed absolutely no effects until after 24-48 hours and opacity after 3 to 7 days. The anterior location of the lens injury is also unusual. The 5.5 GHz operating frequency was not high enough to produce preferential anterior chamber heating (Richardson 1951 and unpublished observations of LEL). The expected site of maximal intra-ocular temperature elevation at 5.5 GHz is retro-lental and the expected opacity would be posterior subcapsular. This strongly suggests that Birenbaum's results are caused by corneal heating via conduction from a hot applicator.

Pulsed fields have been implicated in ultrastructural damage to cell membranes and mitochondria with in vitro exposures of neuroblastoma cells in culture (Webber et al. 1980). The exposures took place at 2.7 GHz with 1 usec pulse width and 330 Hz PRF. Cell membrane blebs and pyriform figures in mitochondria were observed. These could not be duplicated by simple heating to equivalent or higher temperatures.

No comparisons were made to effects caused by CW irradiations but the effect of the heat bath treatment is in contrast to the RMS value of the field. No mention was made of TEE, and the pulse width would be suboptimal for the frequency of operation and target dielectric; nevertheless, TEE could be implicated.

The mechanism not implicated in the contrast of pulse with CW exposure is pearl chain formation. This is an electrostatic effect which causes orientation of dipole objects along force lines during a pulse. In between pulses, Brownian motion disorders the pearl chains. Sher et al (1970) clearly demonstrate that pearl chain formation is not augmented in pulsed fields even though the peak values are higher than the equivalent power implied by static field.

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Figure 1. Diagram of exposure apparatus showing the wave guide structure and glass holder. For irradiation, the lens is located at the bottom of the central glass tube; buffer, pumped into this tube (shown above the lens) circulates in a water jacket around this tube and then passes out an outlet glass tube at one corner of the jacket. The square metal tube through which the tubes enter is a waveguide, which provides in excess of 100 dB attenuation. In addition to the dimensions shown locating the lens, the distance of the lens from the side of the wave guide was 12.86 cm. The lens holder was located 1/4 guide wavelength from the waveguide shorting plate placing the lens holder in the maximum of the electric field. The vertical position of the lens holder was adjusted so that the lens was approximately at the center of waveguide where it may move about (shown by arrows) in the circulating phosphate-buffered saline.

Lens Holder in Waveguide

(Not to scale)

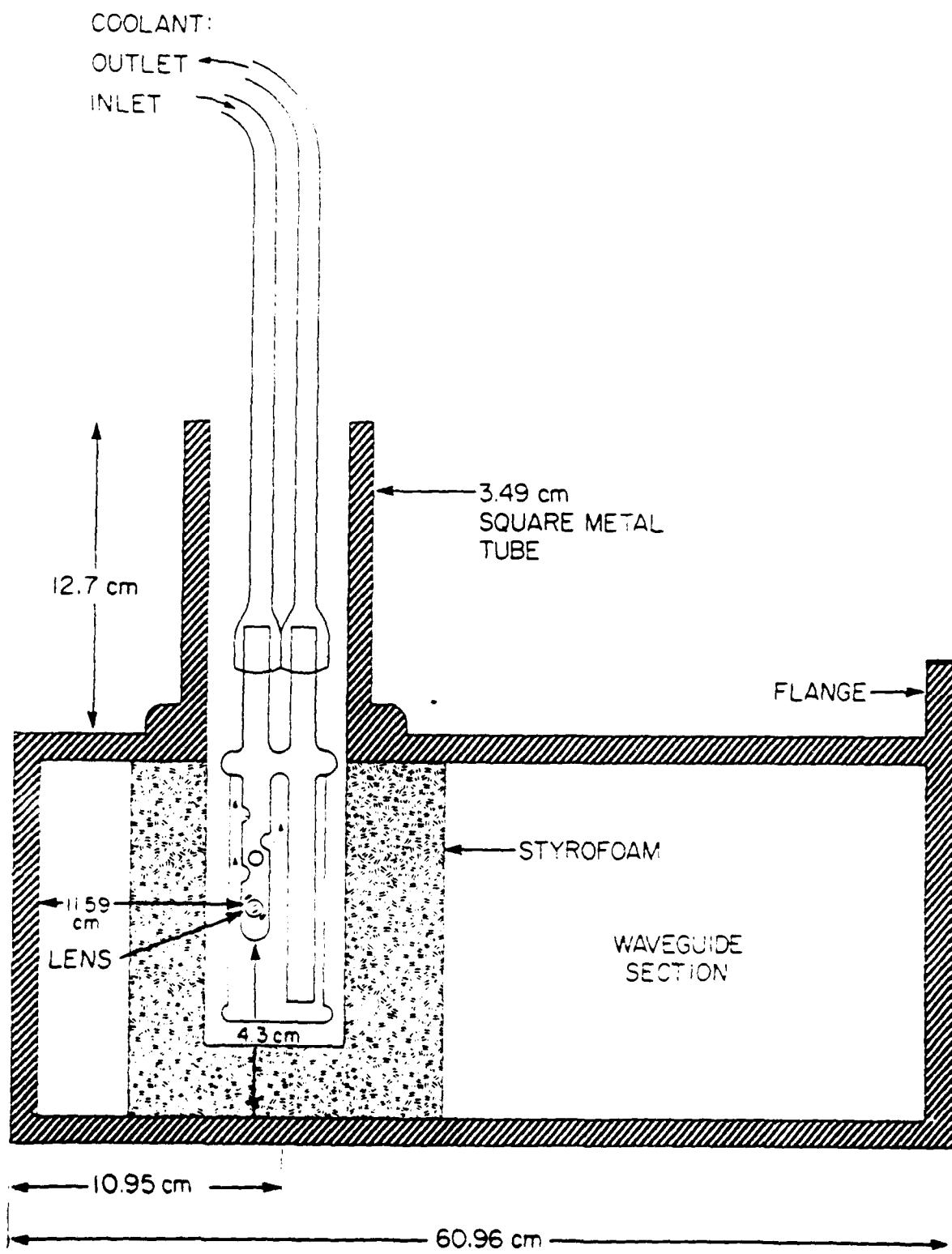


Figure 2. Diagrammatic representation of damage to rat lens observed after exposure to continuous wave (CW) microwaves in vitro. The diagrams show the types and extent of damage observed following irradiation with CW microwaves for the times and SAR values indicated. The absence of any additions to the circular lens outline indicates that no damage was observed. The average subcapsular depth of damage in μm is indicated under each lens shown. The lateral extension of visible damage in μm in the immediate subcapsular area is shown (where appropriate) at the right side of each lens.

OBSERVED AFTER MICROWAVE EXPOSURE USING CW WAVES

WAVELENGTH	SAR mW/g	6 MIN	20 MIN	60 MIN
1400 nm	0.2W	X	()	()
1450 nm	2.3W	X	.	X
1500 nm	5.5W	•	•	•
1550 nm	1W			
1600 nm	11.5W			
1650 nm	23W			
1700 nm	69W			
1750 nm	20W			
1800 nm	230W			
1850 nm	690W			
1900 nm	1022W			
1950 nm	1040W			
2000 nm	1050W			
2050 nm	1060W			
2100 nm	1070W			
2150 nm	1080W			
2200 nm	1090W			
2250 nm	1095W			
2300 nm	1100W			
2350 nm	1105W			
2400 nm	1110W			
2450 nm	1115W			
2500 nm	1120W			
2550 nm	1125W			
2600 nm	1130W			
2650 nm	1135W			
2700 nm	1140W			
2750 nm	1145W			
2800 nm	1150W			
2850 nm	1155W			
2900 nm	1160W			
2950 nm	1165W			
3000 nm	1170W			
3050 nm	1175W			
3100 nm	1180W			
3150 nm	1185W			
3200 nm	1190W			
3250 nm	1195W			
3300 nm	1200W			

Figure 3. Diagrammatic representation of damage to rat lens observed after exposure to pulsed microwaves in vitro. The diagrams illustrate the types and extent of damage observed following irradiation with microwaves for the time and SAR values indicated in the table. The absence of any additions to the circular lens outline indicates that no damage was observed. The average subcapsula depth of damage in μm is indicated under each lens shown. The lateral extension of visible damage in μm in the immediate subcapsula area is shown (where appropriate) at the right side of each lens.

ORCHID MULCH MICROWAVE EXPOSURE USING PULSED WAVES

WATTAGE SAR mw/g	0.2W 0	0.2W 2.3	1W 5.75	1W 11.5	2W 23	6W 69	20W 230	65W 750W/g
6 MINS								
20 MINS								
60 MINS								

NOTE 5, FOAM, GRANULAR

Figure 4. Average damage observed at the equatorial region of lenses irradiated for 6 min. with Pu or CW microwave irradiation in vitro as described in text. Depth of abnormal morphology holes, spherical bodies, foam and granularity of lens cell surfaces are compared for (a) sham-irradiation, (b) control fixed immediately after dissection without irradiation or sham-irradiation, (c) Pu radiation at 40 mW/g, lowest SAR at which abnormal morphology was detected by SEM for Pu irradiation, compared to (d) CW-irradiation also at 40 mW/g, note absence of abnormal morphology, (e) Pu irradiation at 400 mW/g compared to, (f) CW-irradiation at 400 mW/g, lowest SAR at which abnormal morphology was detected for CW, (g) and (h) 1.3 W/g for (g) Pu and (h) CW to permit comparison of extent of damage at highest SAR used for 6 min irradiation.

Figure 5. Average damage observed at the equatorial region of lenses irradiated for 20 min. with Pu or CW irradiation in vitro as described in text. Depth of abnormal morphology holes, spherical bodies, foam and granularity of lens cell surfaces are compared for (a) sham-irradiation, (b) control fixed immediately after dissection without irradiation or sham-irradiation, (c) Pu radiation at 20 mW/g, lowest SAR at which abnormal morphology was detected by SEM for Pu irradiation for 20 min, (d) CW-irradiation also at 20 mW/g for 20 min: note absence of abnormal morphology, (e) Pu irradiation at 40 mW/g compared to, (f) CW-irradiation also at 40 mW/g, lowest SAR at which abnormal morphology was detected, (d) and (h) 1.3 W/g highest SAR used for (g) Pu and (h) CW to permit comparison of extent of damage at highest SAR used for 20 min irradiation.

Figure 6. Average extent of damage observed at the equatorial region of lenses irradiated for 60 min. with Pu or CW irradiation in vitro as described in text. Depth of abnormal morphology holes, spherical bodies, foam and granularity of lens cell surfaces are compared for (a) sham-irradiation, (b) control fixed immediately after dissection without irradiation or sham-irradiation, (c) Pu radiation at 10 mW/g, lowest SAR at which abnormal morphology was detected by SEM for Pu irradiation for 60 min. (d) CW-irradiation also at 10 mW/g 60 min: note slight but lesser in extent) abnormal morphology, (e) Pu irradiation at 120 mW/g, an intermediate SAR value to show greater extent of damage as compared to (f) CW-irradiation also at 120 mW/g, (g) and (h) Pu irradiation at SAR 1.3 W/g highest SAR used for (g) Pu and (h) CW irradiation to permit comparison of extent of damage at highest SAR used for 60 min irradiation.

In Vitro Lenticular Damage Diagrammatic Stripe

Figure 4

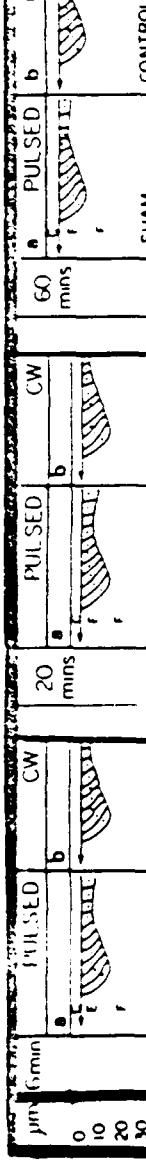


Figure 5

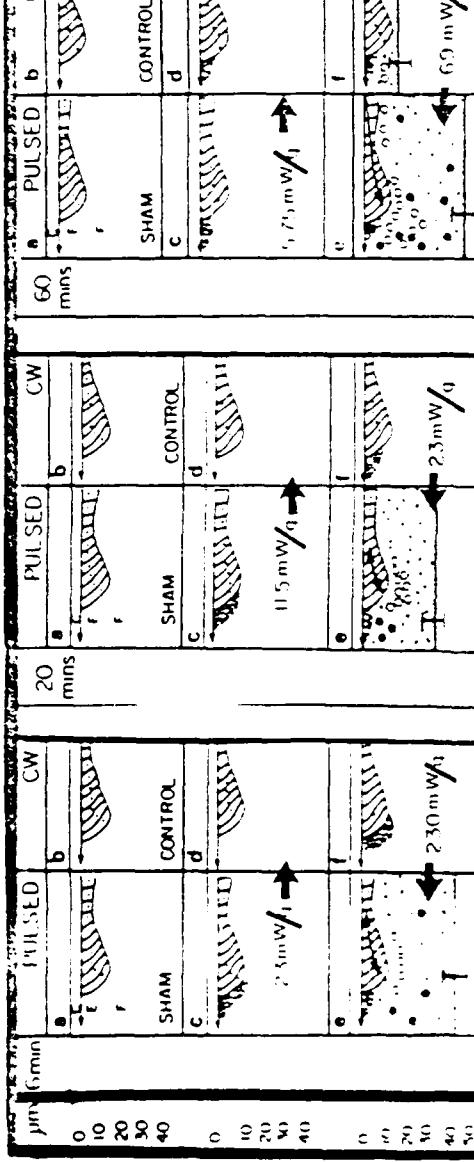
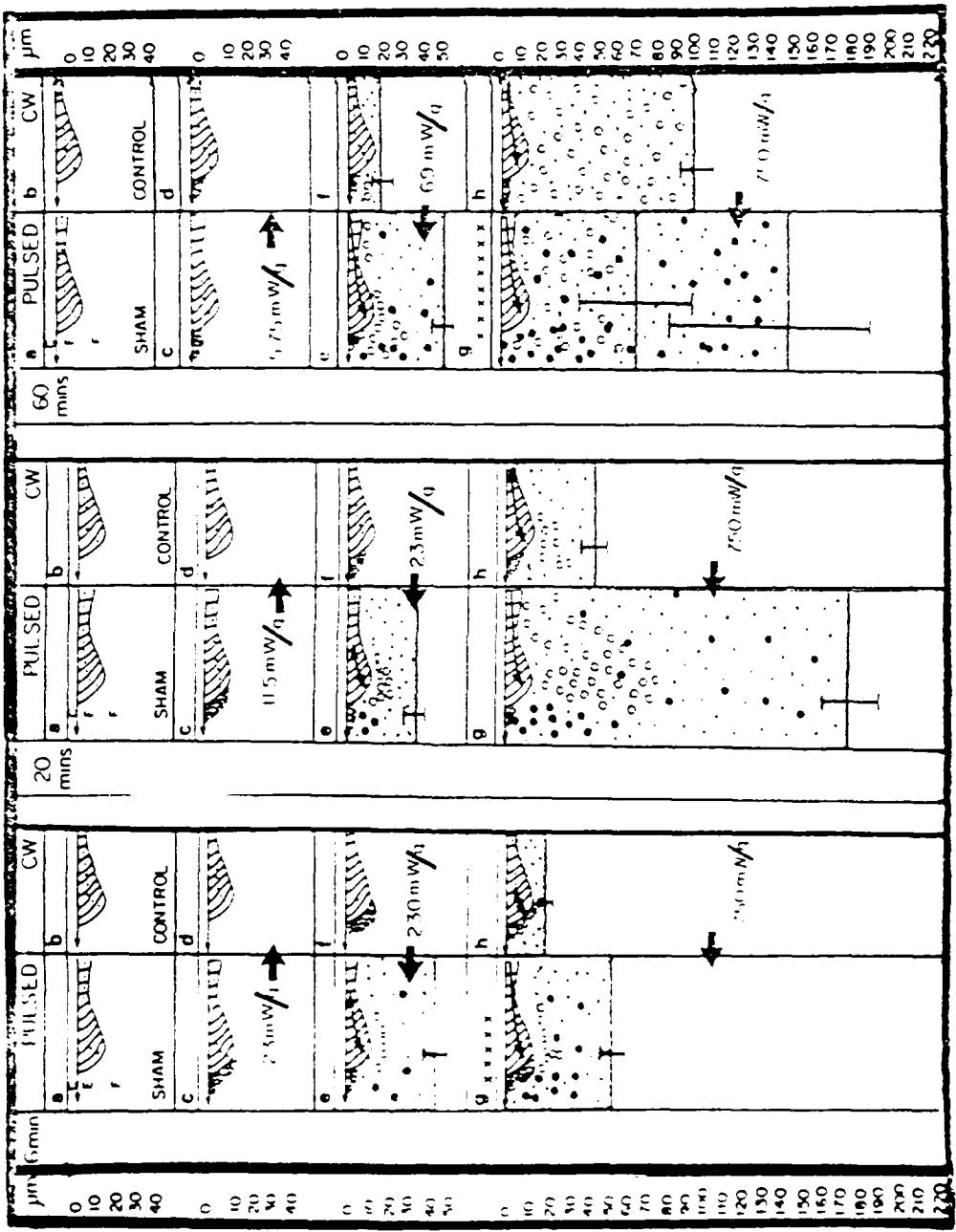


Figure 6



TIME	10 mW/q	20 mW/q	30 mW/q	40 mW/q
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0

Figure 7. Plot of computer-generated curves using the reciprocal model, illustrating the experimentally observed points and the statistically determined best-fit lines for the equation shown in model 1 (F. 3).

RECIPROCAL MODEL

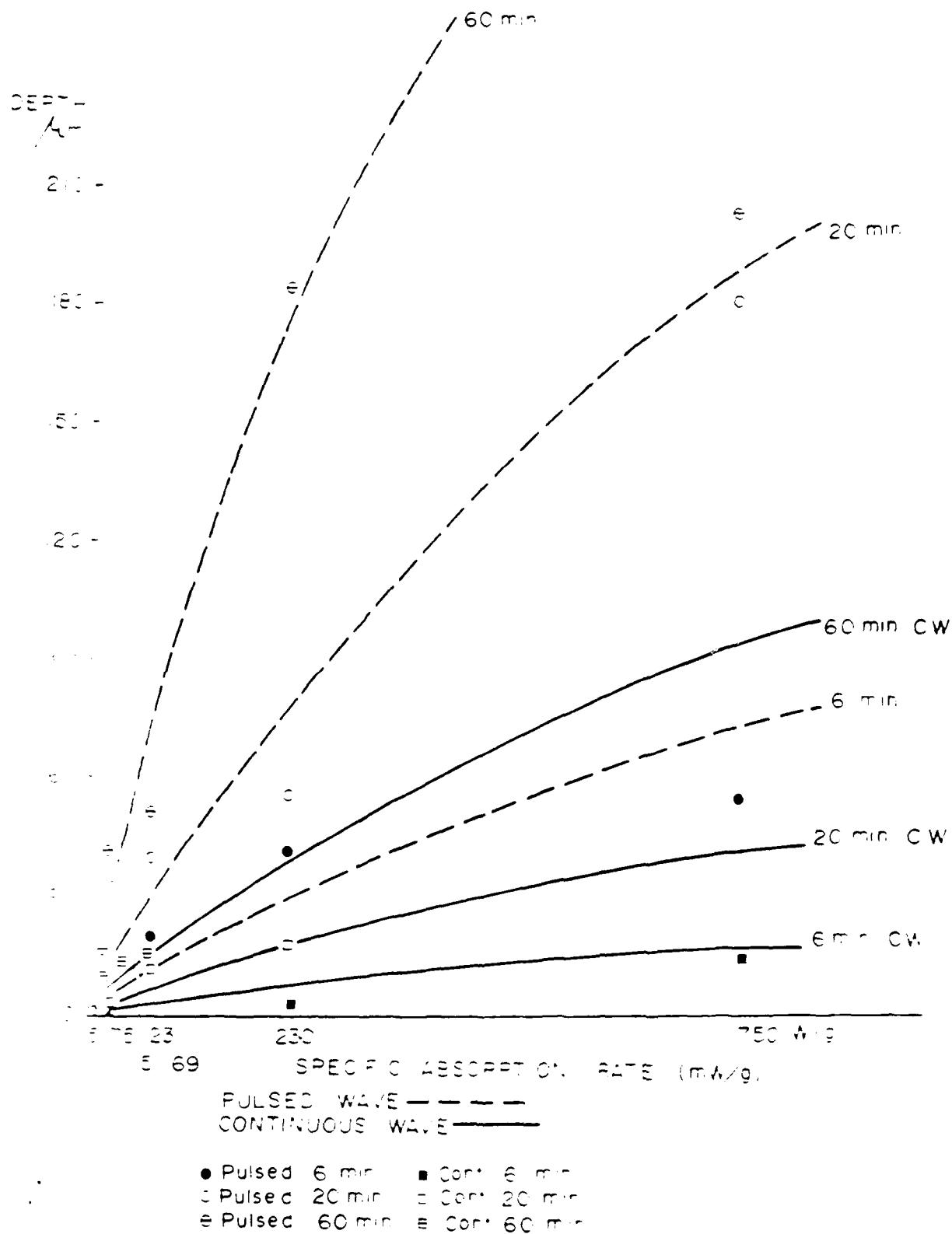


Figure 8. Plot of computer-generated curves using the separate effects model, illustrating the experimentally observed points and the statistically determined best-fit lines for the equation shown in model 2 (F. 3).

SEPARATE EFFECTS MODEL

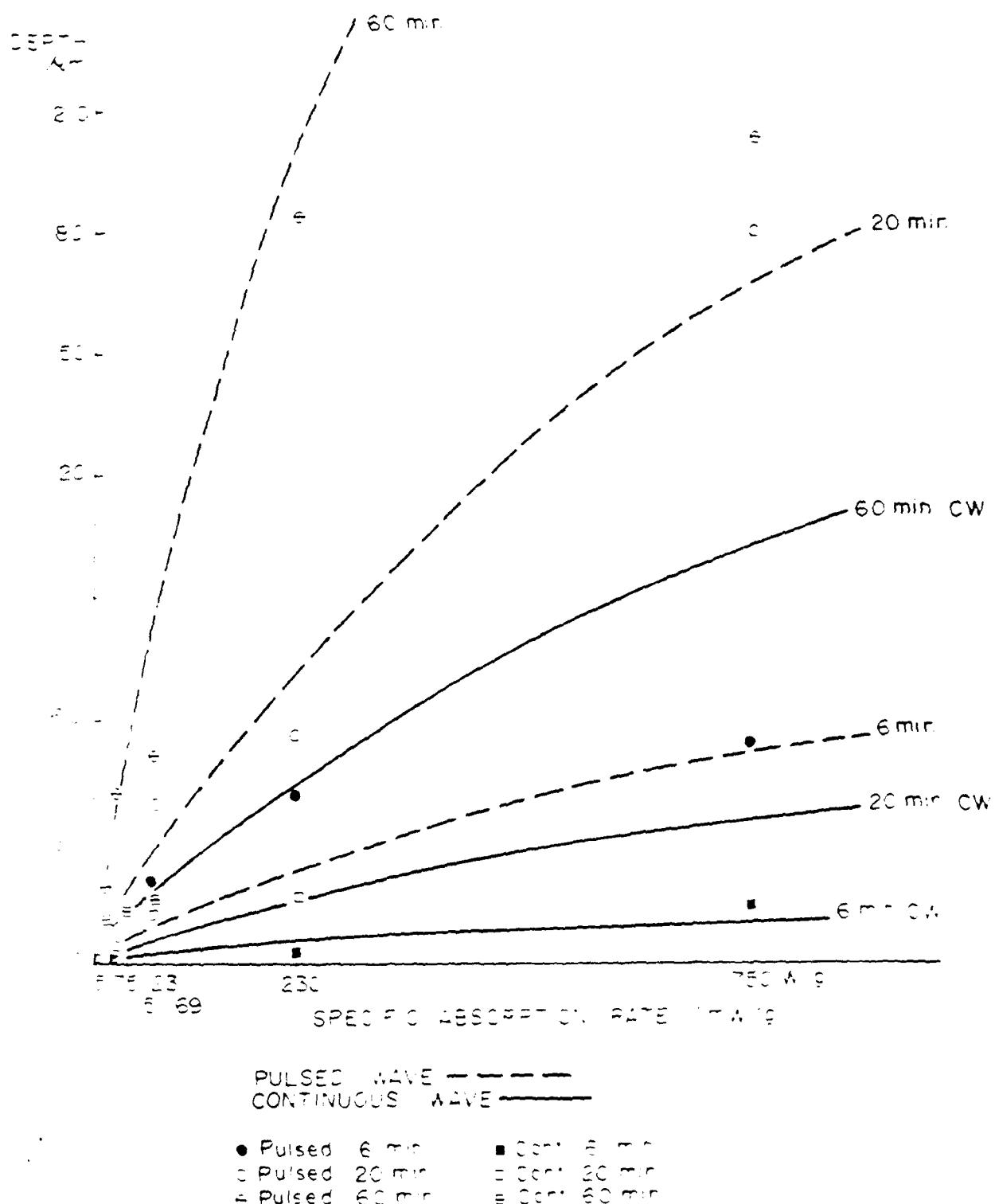


Figure 4. Plot of computer-generated curves for mean depth of damage as a function of an average power or normalized power values, for different peak pulse powers, as outlined in section F. 4.

MEAN DEPTH OF DAMAGE BY AVERAGE POWER AND PEAK POWER

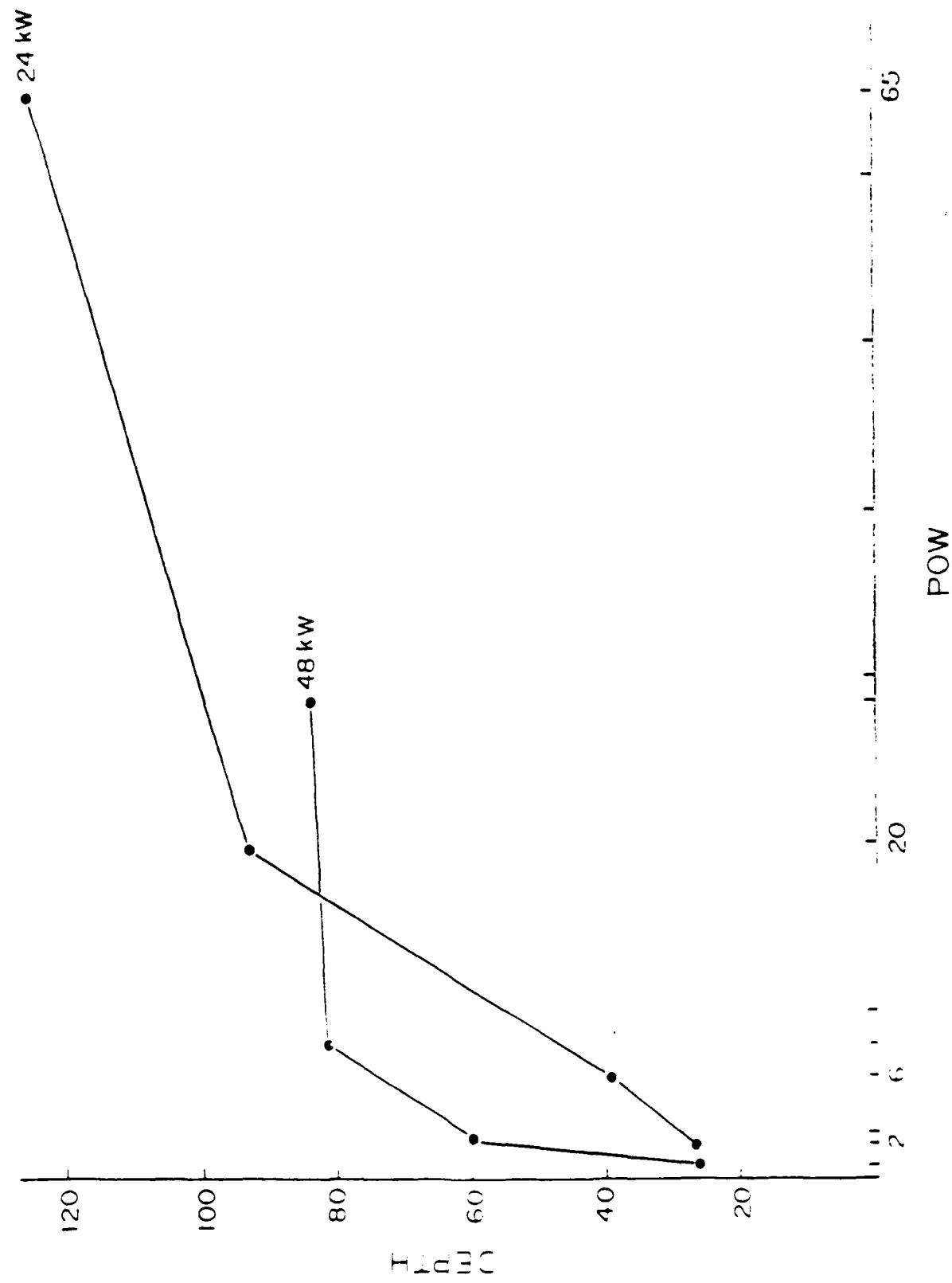


Figure 10. Plot of computer-generated curves of mean depth of damage as a function of average power or normalized power values, for different pulse durations 2, 10 and 20 microseconds, as outlined in section F.4.1.

MINIMUM PULSE WIDTH OF DAMAGE BY AVERAGE POWER AND PULSE WIDTH AT 48 KW

36

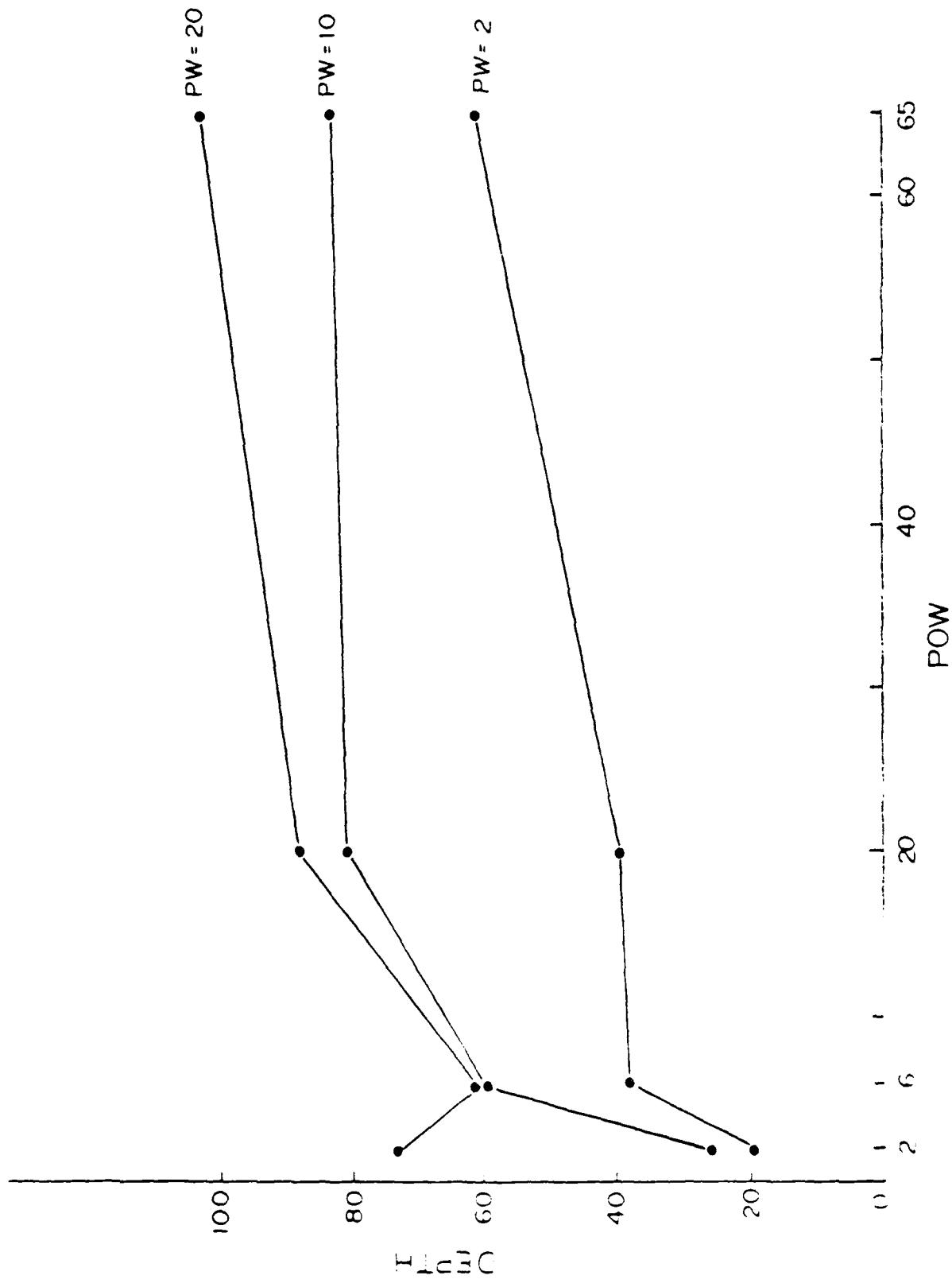


Figure III. Plot of computer-generated curves of mean depth of damage as a function of pulse width for different duration of exposure to irradiation, at 48 KW peak pulse power as outlined in section F.4.1.

MEAN D₁ PTH OF DAMAGE BY PULSE WIDTH AND TIME AT 48 kW

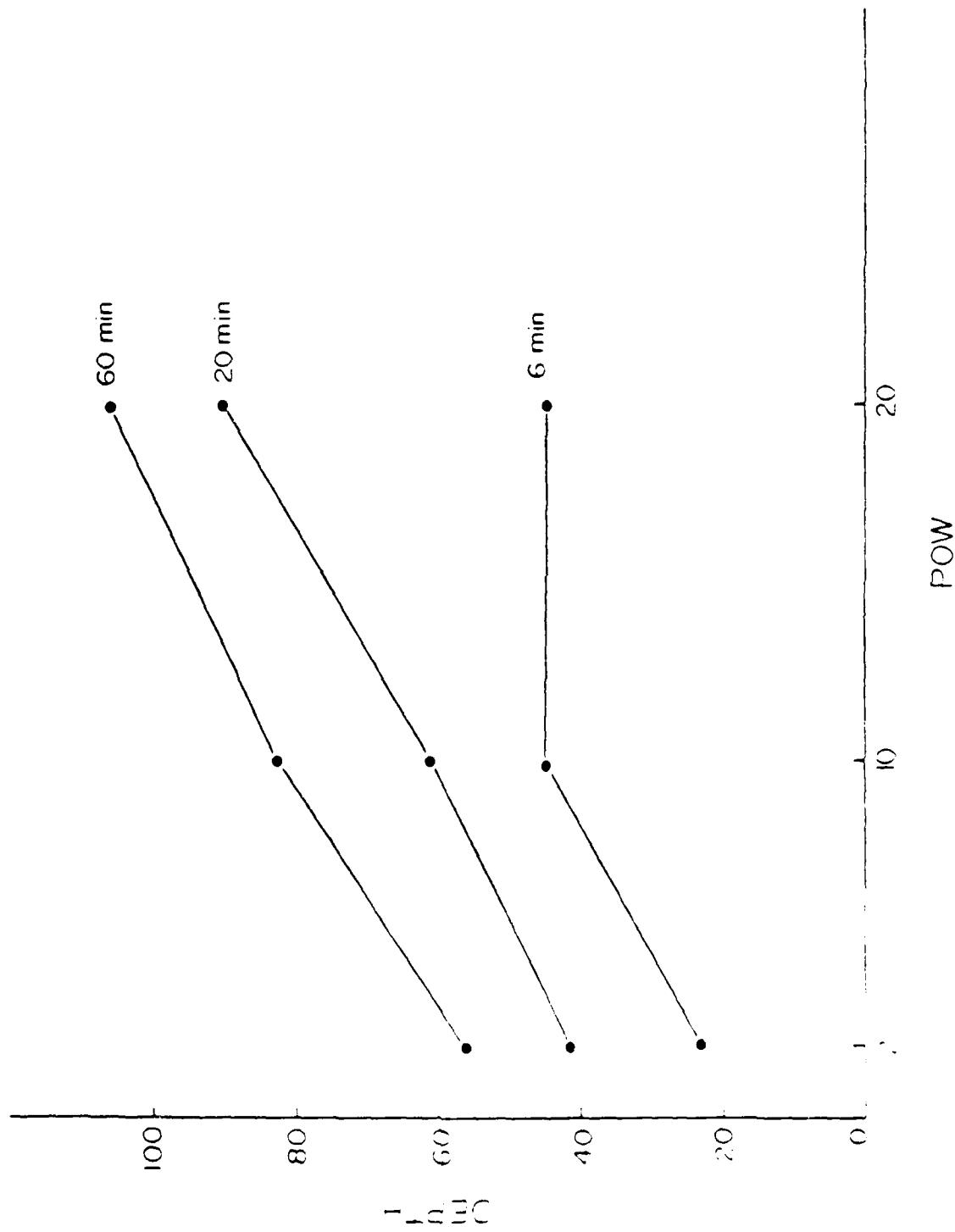


Figure 10. Plot of computer-generated curves of mean depth of damage as a function of average power or normalized power (all at 13 K $^{\circ}$ peak pulse power) for different durations of exposure to irradiation. The details are indicated in section F.4.1.

MIN DEPTH OF DAMAGE BY AVERAGE POWER AND TIME AT 48 KW

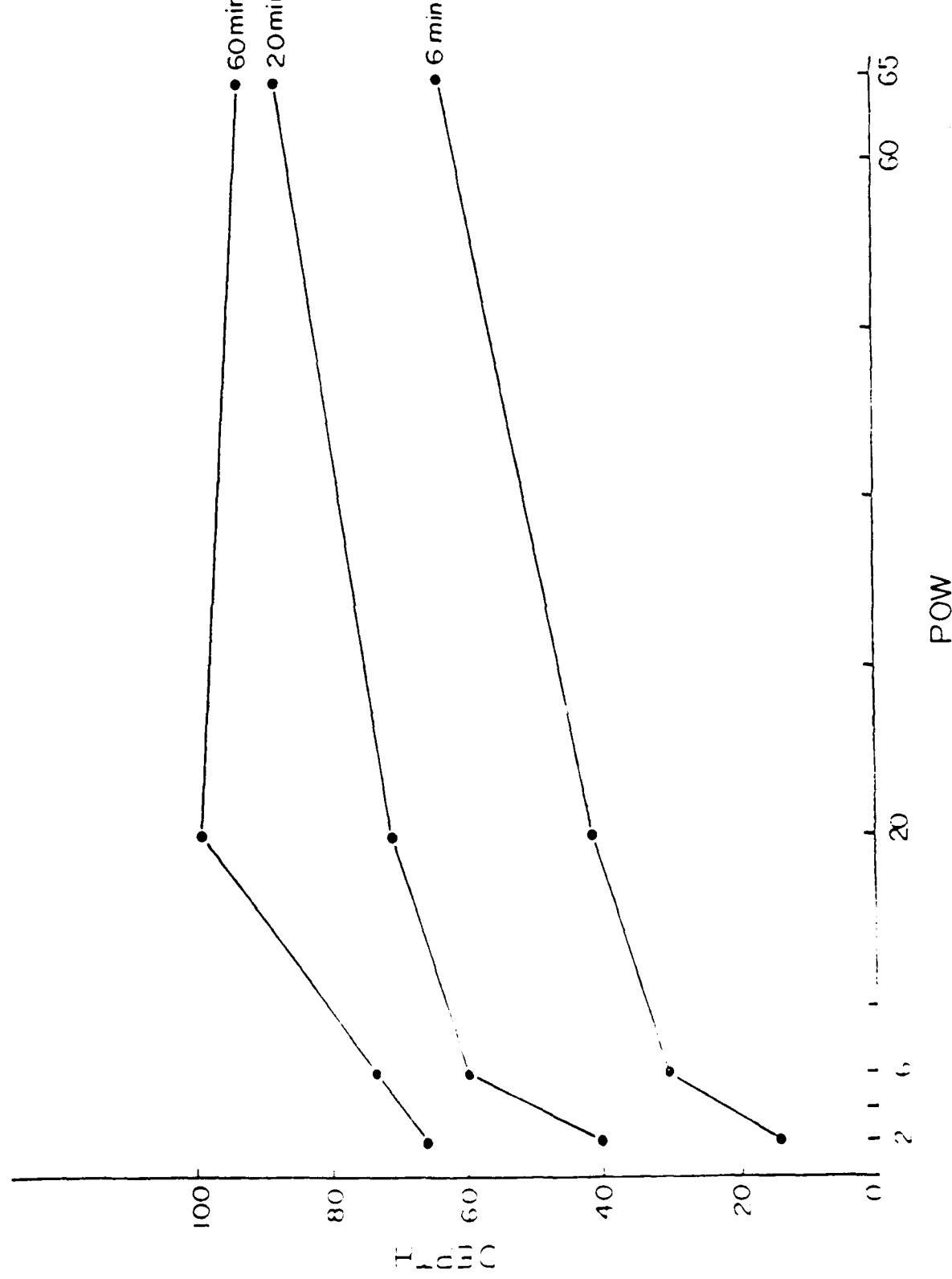


TABLE 1

Threshold of Damage (TD_{50})
(Scanning Electron Microscopy Only)

Time	Type	Normal	Foam	Granulation	Globular Degenera- tion	Holes in Fiber Cells	Capsular Damage
6 min	Pulsed	up to 6W	6W	6W	20W	6W	65W
	CW	up to 20W	20W	65W	---	---	---
20 min	Pulsed	up to 0.5W	0.5W	2W	220W	2W	65W
	CW	up to 0.5W	6W	6W	65W	---	---
60 min	Pulsed	up to 0.5W	---	0.5W	6W	1W	20W
	CW	up to 0.5W	0.5W	6W	65W	65W (1 sample)	---

TABLE 2

Microwave Reciprocity Study (Depth of Damage) for CU Irradiation

Mean Count Sum Std. Dev.	.5 W	1 W	2 W	6 W	20 W	65 W
	1	2	3	4	5	6
6 min.	0	0	0	0	.750	14.436
	0	0	4	3	3	4
	0	0	0	0	2.250	57.750
	0	0	0	0	.661	4.175
20 min.	0	0	.813	11.500	17.250	0
	0	0	4	4	4	0
	0	0	3.250	46.000	69.000	0
	0	0	.555	4.818	5.058	0
60 min.	.500	10.688	14.000	15.625	0	0
	3	4	2	4	0	0
	1.500	42.750	28.00	62.500	0	0
	.500	2.839	4.243	2.810	0	0

TABLE 3

Models with Reciprocal and Separate Effects of Exposure Duration
(TIME) and Dose Rate (POW) for Continuous Waves.

$$\ln(\text{DEP}) = -2.31 + .87 \ln(\text{POW TIME}) \quad \frac{R^2}{.67}$$

$\pm \text{SE} \quad \pm .47 \quad \pm .10$

$$\ln(\text{DEP}) = -3.26 + .82 \ln(\text{POW}) = 1.22 \ln(\text{TIME}) .76$$

$\pm \text{SE} \quad \pm .47 \quad \pm .09 \quad \pm .13$

TABLE 4

Test of Reciprocal vs Separate Effects Models for
Continuous Waves

Source of Variation	Model (1)		Model (2)	
	df	SS	df	SS
Regression	1	38.94	2	44.51
Residual	37	19.26	36	13.69

$$F = \frac{(44.51 - 38.94)/1}{13.69/36} = 14.64 \quad (p < .001)$$

TABLE 5

95% Confidence Intervals for Parameters in Models (1) and (2)

Model	Parameters	Estimate	Confidence Interval
<hr/>			
(1)	b_0	.10	.04 to .26
	b_1	.87	.67 to 1.07
<hr/>			
(2)	b_0	.04	.01 to .10
	b_1	.82	.64 to 1.00
	b_2	1.22	.96 to 1.47

Note: A 95% confidence interval contains the true value of the estimated parameter with probability .95.

TABLE 6

Models with Reciprocal and Separate Effects of
 Exposure Duration (TIME) and Dose Rate (POW)
 for Pulsed and Continuous Waves

R² Reciprocal Effects

.84 $\ln(\text{DEP}) = -1.91 + .78 \ln(\text{POW} \times \text{TIME})$ for continuous
 $= -.36 + .78 \ln(\text{POW} \times \text{TIME})$ for pulsed

SE $\pm .05$

effect of radiation type: $\ln(b_1) = 1.55 \pm .14$

$b_1 = 4.71$ (pulsed is 4.71xCW)

R² Separate Effects

.85 $\ln(\text{DEP}) = -2.41 + .74 \ln(\text{POW}) + .97 \ln(\text{TIME})$ for continuous
 $= -.87 + .74 \ln(\text{POW}) + .97 \ln(\text{TIME})$ for pulsed

effect of radiation type: $\ln(b_1) = 1.54 \pm .13$

$b_1 = 4.66$

TABLE 7

Test of Reciprocal vs Separate Effects Models for
Combined Data for Continuous and Pulsed Waves

Source of Variation	Model (3)		Model (4)	
	dt	SS	dt	SS
Regression	2	200.84	3	204.90
Residual	92	39.61	91	35.56

$$F = \frac{204.90 - 200.84)/1}{35.56/91} \approx 10.41 \quad (p < .005)$$

TABLE 8

Microwave Reciprocity Study (Depth of Damage for Pulsed Irradiation)

Mean	.5 W	1 W	2 W	6 W	20 W	65 W
Count	1	2	3	4	5	6
Sum						
Std. Dev.						
6 min.	0	0	.625	21.433	42.475	51.560
	0	0	4	3	4	5
	0	0	2.500	64.300	169.900	257.800
	0	0	.750	4.704	1.394	6.140
20 min.	4.063	0	33.500	39.813	54.638	180.000
	4	0	4	4	4	4
	16.250	0	134.000	159.250	218.550	720.000
	4.195	0	2.656	2.095	1.775	8.414
60 min.	0	17.750	41.620	51.112	185.625	203.750
	0	5	5	4	4	2
	0	88.750	208.100	204.450	742.500	407.500
	0	3.992	1.702	1.288	8.985	1.768

TABLE 9

95% Confidence Intervals for parameters in Models (3)

and (4)

Model	Parameter	Estimate	Confidence Interval
<hr/>			
(3)	b_0	.15	.09 to .24
	b_1	4.71	3.56 to 6.23
	b_2	.78	.69 to .88
<hr/>			
(4)	b_0	.09	.05 to .16
	b_1	4.66	3.60 to 6.11
	b_2	.74	.65 to .84
	b_3	.97	.82 to 1.12

TABLE I.O

MICROMAX RECIPROCITY STUDY CREDIT DE PASACED

FILE NO NAME (CREATION DATE = 03/06/2011)

25/116/21. 12:55:20

25/116/21. 12:55:20

TIME DURATION OF EXPOSURE

CONTROLLING FOR PEAK POWER

OPEN

VARIABLE AVERAGED... DEP

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County 1 2 DATA 5 DATA 55 DATA 90

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• 250 1 6-204 1 - 254 1 - 140 1

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581-582 583-584 585-586 587-588 589-590 591-592 593-594 595-596 597-598 599-600 601-602 603-604 605-606 607-608 609-610 611-612 613-614 615-616 617-618 619-620 621-622 623-624 625-626 627-628 629-629 630-631 632-633 634-635 636-637 638-639 640-641 642-643 644-645 646-647 648-649 650-651 652-653 654-655 656-657 658-659 660-661 662-663 664-665 666-667 668-669 670-671 672-673 674-675 676-677 678-679 680-681 682-683 684-685 686-687 688-689 690-691 692-693 694-695 696-697 698-699 699-700 701-702 703-704 705-706 707-708 709-709 710-711 712-713 714-715 716-717 718-719 720-721 722-723 724-725 726-727 728-729 730-731 732-733 734-735 736-737 738-739 740-741 742-743 744-745 746-747 748-749 750-751 752-753 754-755 756-757 758-759 760-761 762-763 764-765 766-767 768-769 770-771 772-773 774-775 776-777 778-779 779-780 781-782 783-784 785-786 787-788 789-789 790-791 792-793 794-795 796-797 798-799 799-800 801-802 803-804 805-806 807-808 809-809 810-811 812-813 814-815 816-817 818-819 820-821 822-823 824-825 826-827 828-829 830-831 832-833 834-835 836-837 838-839 840-841 842-843 844-845 846-847 848-849 850-851 852-853 854-855 856-857 858-859 860-861 862-863 864-865 866-867 868-869 870-871 872-873 874-875 876-877 878-879 879-880 881-882 883-884 885-886 887-888 889-889 890-891 892-893 894-895 896-897 898-899 899-900 901-902 903-904 905-906 907-908 909-909 910-911 912-913 914-915 916-917 918-919 920-921 922-923 924-925 926-927 928-929 930-931 932-933 934-935 936-937 938-939 940-941 942-943 944-945 946-947 948-949 950-951 952-953 954-955 956-957 958-959 960-961 962-963 964-965 966-967 968-969 970-971 972-973 974-975 976-977 978-979 979-980 981-982 983-984 985-986 987-988 989-989 990-991 992-993 994-995 996-997 998-999 999-1000 1001-1002 1003-1004 1005-1006 1007-1008 1009-1009 1010-1011 1012-1013 1014-1015 1016-1017 1018-1019 1020-1021 1022-1023 1024-1025 1026-1027 1028-1029 1030-1031 1032-1033 1034-1035 1036-1037 1038-1039 1040-1041 1042-1043 1044-1045 1046-1047 1048-1049 1050-1051 1052-1053 1054-1055 1056-1057 1058-1059 1060-1061 1062-1063 1064-1065 1066-1067 1068-1069 1070-1071 1072-1073 1074-1075 1076-1077 1078-1079 1079-1080 1081-1082 1083-1084 1085-1086 1087-1088 1089-1089 1090-1091 1092-1093 1094-1095 1096-1097 1098-1099 1099-1100 1101-1102 1103-1104 1105-1106 1107-1108 1109-1109 1110-1111 1112-1113 1114-1115 1116-1117 1118-1119 1120-1121 1122-1123 1124-1125 1126-1127 1128-1129 1130-1131 1132-1133 1134-1135 1136-1137 1138-1139 1140-1141 1142-1143 1144-1145 1146-1147 1148-1149 1150-1151 1152-1153 1154-1155 1156-1157 1158-1159 1160-1161 1162-1163 1164-1165 1166-1167 1168-1169 1170-1171 1172-1173 1174-1175 1176-1177 1178-1179 1179-1180 1181-1182 1183-1184 1185-1186 1187-1188 1189-1189 1190-1191 1192-1193 1194-1195 1196-1197 1198-1199 1199-1200 1201-1202 1203-1204 1205-1206 1207-1208 1209-1209 1210-1211 1212-1213 1214-1215 1216-1217 1218-1219 1220-1221 1222-1223 1224-1225 1226-1227 1228-1229 1230-1231 1232-1233 1234-1235 1236-1237 1238-1239 1240-1241 1242-1243 1244-1245 1246-1247 1248-1249 1250-1251 1252-1253 1254-1255 1256-1257 1258-1259 1260-1261 1262-1263 1264-1265 1266-1267 1268-1269 1270-1271 1272-1273 1274-1275 1276-1277 1278-1279 1279-1280 1281-1282 1283-1284 1285-1286 1287-1288 1289-1289 1290-1291 1292-1293 1294-1295 1296-1297 1298-1299 1299-1300 1301-1302 1303-1304 1305-1306 1307-1308 1309-1309 1310-1311 1312-1313 1314-1315 1316-1317 1318-1319 1320-1321 1322-1323 1324-1325 1326-1327 1328-1329 1330-1331 1332-1333 1334-1335 1336-1337 1338-1339 1340-1341 1342-1343 1344-1345 1346-1347 1348-1349 1350-1351 1352-1353 1354-1355 1356-1357 1358-1359 1360-1361 1362-1363 1364-1365 1366-1367 1368-1369 1370-1371 1372-1373 1374-1375 1376-1377 1378-1379 1379-1380 1381-1382 1383-1384 1385-1386 1387-1388 1389-1389 1390-1391 1392-1393 1394-1395 1396-1397 1398-1399 1399-1400 1401-1402 1403-1404 1405-1406 1407-1408 1409-1409 1410-1411 1412-1413 1414-1415 1416-1417 1418-1419 1420-1421 1422-1423 1424-1425 1426-1427 1428-1429 1430-1431 1432-1433 1434-1435 1436-1437 1438-1439 1440-1441 1442-1443 1444-1445 1446-1447 1448-1449 1450-1451 1452-1453 1454-1455 1456-1457 1458-1459 1460-1461 1462-1463 1464-1465 1466-1467 1468-1469 1470-1471 1472-1473 1474-1475 1476-1477 1478-1479 1479-1480 1481-1482 1483-1484 1485-1486 1487-1488 1489-1489 1490-1491 1492-1493 1494-1495 1496-1497 1498-1499 1499-1500 1501-1502 1503-1504 1505-1506 1507-1508 1509-1509 1510-1511 1512-1513 1514-1515 1516-1517 1518-1519 1520-1521 1522-1523 1524-1525 1526-1527 1528-1529 1530-1531 1532-1533 1534-1535 1536-1537 1538-1539 1540-1541 1542-1543 1544-1545 1546-1547 1548-1549 1550-1551 1552-1553 1554-1555 1556-1557 1558-1559 1560-1561 1562-1563 1564-1565 1566-1567 1568-1569 1570-1571 1572-1573 1574-1575 1576-1577 1578-1579 1579-1580 1581-1582 1583-1584 1585-1586 1587-1588 1589-1589 1590-1591 1592-1593 1594-1595 1596-1597 1598-1599 1599-1600 1601-1602 1603-1604 1605-1606 1607-1608 1609-1609 1610-1611 1612-1613 1614-1615 1616-1617 1618-1619 1620-1621 1622-1623 1624-1625 1626-1627 1628-1629 1630-1631 1632-1633 1634-1635 1636-1637 1638-1639 1640-1641 1642-1643 1644-1645 1646-1647 1648-1649 1650-1651 1652-1653 1654-1655 1656-1657 1658-1659 1660-1661 1662-1663 1664-1665 1666-1667 1668-1669 1670-1671 1672-1673 1674-1675 1676-1677 1678-1679 1679-1680 1681-1682 1683-1684 1685-1686 1687-1688 1689-1689 1690-1691 1692-1693 1694-1695 1696-1697 1698-1699 1699-1700 1701-1702 1703-1704 1705-1706 1707-1708 1709-1709 1710-1711 1712-1713 1714-1715 1716-1717 1718-1719 1720-1721 1722-1723 1724-1725 1726-1727 1728-1729 1730-1731 1732-1733 1734-1735 1736-1737 1738-1739 1740-1741 1742-1743 1744-1745 1746-1747 1748-1749 1750-1751 1752-1753 1754-1755 1756-1757 1758-1759 1760-1761 1762-1763 1764-1765 1766-1767 1768-1769 1770-1771 1772-1773 1774-1775 1776-1777 1778-1779 1779-1780 1781-1782 1783-1784 1785-1786 1787-1788 1789-1789 1790-1791 1792-1793 1794-1795 1796-1797 1798-1799 1799-1800 1801-1802 1803-1804 1805-1806 1807-1808 1809-1809 1810-1811 1812-1813 1814-1815 1816-1817 1818-1819 1820-1821 1822-1823 1824-1825 1826-1827 1828-1829 1830-1831 1832-1833 1834-1835 1836-1837 1838-1839 1840-1841 1842-1843 1844-1845 1846-1847 1848-1849 1850-1851 1852-1853 1854-1855 1856-1857 1858-1859 1860-1861 1862-1863 1864-1865 1866-1867 1868-1869 1870-1871 1872-1873 1874-1875 1876-1877 1878-1879 1879-1880 1881-1882 1883-1884 1885-1886 1887-1888 1889-1889 1890-1891 1892-1893 1894-1895 1896-1897 1898-1899 1899-1900 1901-1902 1903-1904 1905-1906 1907-1908 1909-1909 1910-1911 1912-1913 1914-1915 1916-1917 1918-1919 1920-1921 1922-1923 1924-1925 1926-1927 1928-1929 1930-1931 1932-1933 1934-1935 1936-1937 1938-1939 1940-1941 1942-1943 1944-1945 1946-1947 1948-1949 1950-1951 1952-1953 1954-1955 1956-1957 1958-1959 1960-1961 1962-1963 1964-1965 1966-1967 1968-1969 1970-1971 1972-1973 1974-1975 1976-1977 1978-1979 1979-1980 1981-1982 1983-1984 1985-1986 1987-1988 1989-1989 1990-1991 1992-1993 1994-1995 1996-1997 1998-1999 1999-2000 2001-2002 2003-2004 2005-2006 2007-2008 2009-2009 2010-2011 2012-2013 2014-2015 2016-2017 2018-2019 2020-2021 2022-2023 2024-2025 2026-2027 2028-2029 2030-2031 2032-2033 2034-2035 2036-2037 2038-2039 2040-2041 2042-2043 2044-2045 2046-2047 2048-2049 2050-2051 2052-2053 2054-2055 2056-2057 2058-2059 2060-2061 2062-2063 2064-2065 2066-2067 2068-2069 2070-2071 2072-2073 2074-2075 2076-2077 2078-2079 2079-2080 2081-2082 2083-2084 2085-2086 2087-2088 2089-2089 2090-2091 2092-2093 2094-2095 2096-2097 2098-2099 2099-2100 2101-2102 2103-2104 2105-2106 2107-2108 2109-2109 2110-2111 2112-2113 2114-2115 2116-2117 2118-2119 2120-2121 2122-2123 2124-2125 2126-2127 2128-2129 2130-2131 2132-2133 2134-2135 2136-2137 2138-2139 2140-2141 2142-2143 2144-2145 2146-2147 2148-2149 2150-2151 2152-2153 2154-2155 2156-2157 2158-2159 2160-2161 2162-2163 2164-2165 2166-2167 2168-2169 2170-2171 2172-2173 2174-2175 2176-2177 2178-2179 2179-2180 2181-2182 2183-2184 2185-2186 2187-2188 2189-2189 2190-2191 2192-2193 2194-2195 2196-2197 2198-2199 2199-2200 2201-2202 2203-2204 2205-2206 2207-2208 2209-2209 2210-2211 2212-2213 2214-2215 2216-2217 2218-2219 2220-2221 2222-2223 2224-2225 2226-2227 2228-2229 2230-2231 2232-2233 2234-2235 2236-2237 2238-2239 2240-2241 2242-2243 2244-2245 2246-2247 2248-2249 2250-2251 2252-2253 2254-2255 2256-2257 2258-2259 2260-2261 2262-2263 2264-2265 2266-2267 2268-2269 2270-2271 2272-2273 2274-2275 2276-2277 2278-2279 2279-2280 2281-2282 2283-2284 2285-2286 2287-2288 2289-2289 2290-2291 2292-2293 2294-2295 2296-2297 2298-2299 2299-2300 2301-2302 2303-2304 2305-2306 2307-2308 2309-2309 2310-2311 2312-2313 2314-2315 2316-2317 2318-2319 2320-2321 2322-2323 2324-2325 2326-2327 2328-2329 2330-2331 2332-2333 2334-2335 2336-2337 2338-2339 2340-2341 2342-2343 2344-2345 2346-2347 2348-2349 2350-2351 2352-2353 2354-2355 2356-2357 2358-2359 2360-2361 2362-2363 2364-2365 2366-2367 2368-2369 2370-2371 2372-2373 2374-2375 2376-2377 2378-2379 2379-2380 2381-2382 2383-2384 2385-2386 2387-2388 2389-2389 2390-2391 2392-2393 2394-2395 2396-2397 2398-2399 2399-2400 2401-2402 2403-2404 2405-2406 2407-2408 2409-2409 2410-2411 2412-2413 2414-2415 2416-2417 2418-2419 2420-2421 2422-2423 2424-2425 2426-2427 2428-2429 2430-2431 2432-2433 2434-2435 2436-2437 2438-2439 2440-2441 2442-2443 2444-2445 2446-2447 2448-2449 2450-2451 2452-2453 2454-2455 2456-2457 2458-2459 2460-2461 2462-2463 2464-2465 2466-2467 2468-2469 2470-2471 2472-2473 2474-2475 2476-2477 2478-2479 2479-2480 2481-2482 2483-2484 2485-2486 2487-2488 2489-2489 2490-2491 2492-2493 2494-2495 2496-2497 2498-2499 2499-2500 2501-2502 2503-2504 2505-2506 2507-2508 2509-2509 2510-2511 2512-2513 2514-2515 2516-2517 2518-2519 2520-2521 2522-2523 2524-2525 2526-2527 2528-2529 2530-2531 2532-2533 2534-2535 2536-2537 2538-2539 2540-2541 2542-2543 2544-2545 2546-2547 2548-2549 2550-2551 2552-2553 2554-2555 2556-2557 2558-2559 2560-2561 2562-2563 2564-2565 2566-2567 2568-2569 2570-2571 2572-2573 2574-2575 2576-2577 2578-2579 2579-2580 2581-2582 2583-2584 2585-2586 2587-2588 2589-2589 2590-2591 2592-2593 2594-2595 2596-2597 2598-2599 2599-2600 2601-2602 2603-2604 2605-2606 2607-2608 2609-2609 2610-2611 2612-2613 2614-2615 2616-2617 2618-2619 2620-2621 2622-2623 2624-2625 2626-2627 2628-2629 2630-2631 2632-2633 2634-2635 2636-2637 2638-2639 2640-2641 2642-2643 2644-2645 2646-2647 2648-2649 2650-2651 2652-2653 2654-2655 2656-2657 2658-2659 2660-2661 2662-2663 2664-2665 2666-2667 2668-2669 2670-2671 2672-2673 2674-2675 2676-2677 2678-2679 2679-2680 2681-2682 2683-2684 2685-2686 2687-2688 2689-2689 2690-2691 2692-2693 2694-2695 2696-2697 2698-2699 2699-2700 2701-2702 2703-2704 2705-2706 2707-2708 2709-2709 2710-2711 2712-2713 2714-2715 2716-2717 2718-2719 2720-2721 2722-2723 2724-2725 2726-2727 2728-2729 2730-2731 2732-2733 2734-2735 2736-2737 2738-2739 2740-2741 2742-2743 2744-2745 2746-2747 2748-2749 2750-2751 2752-2753 2754-2755 2756-2757 2758-2759 2760-2761 2762-2763 2764-2765 2766-2767 2768-2769 2770-2771 2772-2773 2774-2775 2776-2777 2778-2779 2779-2780 2781-2782 2783-2784 2785-2786 2787-2788 2789-2789 2790-2791 2792-2793 2794-2795 2796-2797 2798-2799 2799-2800 2801-2802 2803-2804 2805-2806 2807-2808 2809-2809 2810-2811 2812-2813 2814-2815 2816-2817 2818-2819 2820-2821 2822-2823 2824-2825 2826-2827 2828-2829 2830-2831 2832-2833 2834-2835 2836-2837 2838-2839 2840-2841 2842-2843 2844-2845 2846-2847 2848-2849 2850-2851

136-070 1 153-250 1 219 550 1 220 000 1

ITEM	COLUMN	ITEM	COLUMN
26.508	38-309	36.266	125-436
13	11	12	1
364-600	428-000	1130-750	1385-300
11.375	12.560	67.860	71.331

TABLE 11

MICROWAVE RECIEVING STUDY (DEPTH OF DAMAGE)

FILE NUMBER CREATION DATE - 15/04/1970

P.O. 04/21. 12.55.27.

TIME DURATION OF EXPOSURE

CONTROLLING FOR PEAK POWER

VARIABLE AVERAGED DEP

POW

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Table 12: P-Values and Means From ANCOVA of Depth of Damage

<u>Factor</u>	<u>P-Value</u>	
NPOW (Covariate)	.001	(Regression Coefficient=1.4)
PEAK POWER (PP)	.02	
TIME	.001	
PPxTIME	.01	
<u>PP</u>	<u>Means</u>	<u>Adjusted Means</u>
24	70.0	57.8
48	61.3	74.7
<u>TIME</u>		
6	38.2	33.3
20	69.4	67.3
60	94.5	102.8

END OF FILE ON FILE INPUT
AFTER READING 100 CASES FROM SUBFILE NONAME

MICROWAVE RECEPTION STATION (00000000000000000000000000000000)

FILE NUMBER (UR-ALION DATE = 11/03/03.)

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TIME DILATATION OF EXPOSURE

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MEAN COUNT	2 WATTS	6 WATTS	20 WATTS	65 WATTS	RCW	TOTAL
STD. DEV.	3	4	5	6	1	1
6 MINUTES	9.000	37.500	49.000	80.500	64.000	1
	9.000	37.500	49.000	80.500	175.000	4
	0	0	0	0	29.578	
20 MINUTES	46.000	43.000	67.500	135.000	72.875	1
	46.000	43.000	67.500	135.000	291.500	4
	0	0	0	0	42.830	
60 MINUTES	67.500	80.500	180.000	168.000	124.000	1
	67.500	80.500	180.000	168.000	496.000	4
	0	0	0	0	58.185	
TOTAL COLUMN	40.333	53.667	98.833	127.833	80.292	1
	3	3	3	3	3	
	122.500	161.000	296.500	383.500	963.500	
	29.578	23.400	70.898	44.188	53.440	

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TABLE 13

TABLE I

MICROWAVE RECEIVERSITY STUDY (DEPTH OF DAMAGE)

FILE: NOVATE (LOCATION DATE = 1971/04/10, 00:00:00)

1967/04/19. 11.45.2a.

TIME DURATION OF EXPOSURE

CONTROLLING = 0.25 PULSE WIDTH

VARIABLE AVERAGE DEP

POW

WAVE

POWER

TIME PUMP IN WATTS

VALUE.. 3 10 US

TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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TABLE 15

MICROWAVE RECEIVERSITY STUDY (DEPTH OF DAMAGE)

1915 NOVEMBER 25 (1915/11/25)

86 / 116 / 1A. 11.45.2A.

CONTROLLING POLLUTION OF RIVERS

AVANTAGE OF POWER PLANTS

BRITISH ASSOCIATION FOR THE HISTORY OF SCIENCE

Table 17: P-Values From ANOVA on 48 Kw Data

<u>Factor</u>	<u>P-Value</u>
PULSE WIDTH (PW)	.001
POWER (POW)	.001
TIME	.001
PWxPOW	.001
PWxTIME	.001
POWxTIME	.79
PWxPOWxTIME	.007

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